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Procedia Engineering 28 (2012) 604 – 607

**Procedia
Engineering**www.elsevier.com/locate/procedia

2012 International Conference on Modern Hydraulic Engineering

Regional Analysis of Extreme Temperature Indices for the Haihe River Basin from 1960 to 2009

Cuiping Zhao, Weiguang Wang, Wanqiu Xing, a*

State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Hohai University, Nanjing 210098, China

Abstract

In this paper, spatial and temporal patterns of changes in extreme temperature are investigated by using 15 extreme temperature indices based on 32 meteorological stations data for the period 1960-2009 in Haihe River basin, with the help of simple linear regression method, Mann-Kendall trend test and GIS technique. Results show that all temperature extreme indices present significant change except TXx with a non-significant positive trend in the Haihe basin. In almost whole basin, FD, ID, TN10p, TX10p, CSDI and DTR displayed significant negative trend. While SU25, GSL, TMAXmean, TMINmean, TNn, TN90p, TX90p and WSDI exhibited significant positive trend. The slopes for indices related to low temperature are larger than that of indices related to high temperature. Furthermore, the trends for TN90p, TX90p and WSDI were respectively almost opposite to TN10p, TX10p and CSDI in the Haihe River basin.

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Keywords: the Haihe River basin; climate extreme; climate extreme indices; climate changes

1. Introduction

The Global warming may be exerting increasing impacts on global hydrological cycle and human society, which had been documented in the reports of the IPCC (2007). Because of the severe ecological, social and economical consequences of the disasters that extreme weather conditions caused, overwhelming public concerns have been put on the extreme climate events. More than 70% of global land demonstrated significant positive trend for cool nights and negative trend for warm nights [1]. And Yan et al. (2002) [2] found a gradual reduction of the number of cold days in China over the 20th century

* Corresponding author. Cuiping Zhao, Tel.: 013770516607.

E-mail address: zhaocuiping139@163.com.

and an increase in the number of warm days only since 1961.

The Haihe River basin provides water resources for agriculture and industry in North China, in which there is an increasing and acute shortage of water. This increase in extreme events is different from region to region over China [3]. Therefore, exploring and understanding statistical characteristics of the extreme climatic events will be considerably important.

2. Data

Daily time series of temperature (minimum and maximum) of 32 stations for 1960-2009 from Haihe River catchment were available in this study (Figure 1). The missing data in 1 day has been filled in by average value of neighboring days, while the ones exceeding 1 day has been filled in based on the neighboring stations. It is considered as non-influence gap filling method on the long-term temporal trend [3]. The quality control procedure in RCLimDex was taken advantaged to identify errors and the RHtestV3 software package was used to check data homogeneity.

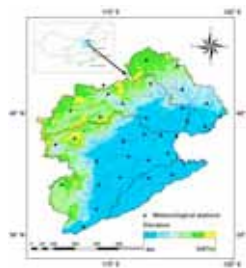


Figure 1. Geographical locations of meteorological stations in the Haihe River Basin.

3. Indices and Method

15 extreme temperature indices (Table 1) were chosen from the list of indices recommended by the ETCCDMI. Meanwhile, the definitions of these selected indices referred to ETCCDMI. The RCLimDEX software package was developed and maintained to calculate the indices of climate extremes for monitoring and detecting climate change [4].

The arithmetic average method was adopted to calculate the regional trends from the individual stations. Simple linear regression method and Mann-kendall trend test are used to calculate the trends for temperature extreme indices and to identify whether or not trends were significant at the 0.05 level.

4. Results and discussion

The spatial trends for selected extreme indices are demonstrated in figure 2 and Table 1. Apart from TXX, trends of the rest indices are significant at the 0.05 level in the Haihe River basin. In order to better research climate changes, these extreme indices will be studied further.

4.1. FD, ID, SU25 and GSL

In the whole Haihe basin, stations characterized by significantly decreasing trend of FD account for 90.6% of the total stations. A remarkably large increasing trend in FD was found in Chengde and Yushe station (Figure 2 (A)). On the contrary, apart from the two stations mentioned above which had a weak and non-significant negative trend, four fifths of stations showed significant positive trend for GSL in the

whole basin (Figure 2 (D)). It can be seen that all stations displayed negative trend for ID in the Haihe catchment. The large-magnitude decrease was found in the east of basin (Figure 2 (B)). All stations experienced positive trend for SU25 except Raoyang station. Stations with significantly increasing trends account for 50% of the total and most of them were located in the northern (Figure 2 (C)). And FD (GSL) presented the larger decrease (increase) rate than ID (SU25) (Table 1).

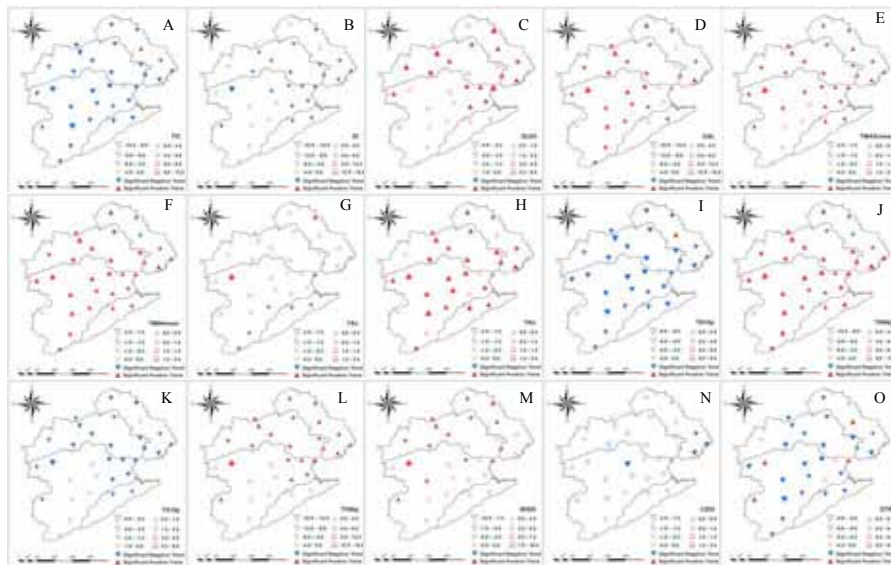


Figure 2. Trends per decade in FD (days/decade), ID (days/decade), SU25 (days/decade), GSL (days/decade), TMAXmean ($^{\circ}\text{C}/\text{decade}$), TMINmean ($^{\circ}\text{C}/\text{decade}$), TXx ($^{\circ}\text{C}/\text{decade}$), TNn ($^{\circ}\text{C}/\text{decade}$), TN10p (days/decade), TN90p (days/decade), TX10p (days/decade), TX90p (days/decade), WSDI (days/decade), CSDI (days/decade) and DTR ($^{\circ}\text{C}/\text{decade}$) for the 1960-2009 period in Haihe River basin. Upward and downward triangles represent positive and negative trends respectively. Different sizes of triangles indicate different magnitudes of decadal trend. The solid triangles represent positive and negative trends at the 5% level.

Table 1. Selected indices for analysis of extreme temperature in Haihe basin

Index	Units (decade)	Test Z	Slope (decade)	Index	Units (decade)	Test Z	Slope (decade)
FD	Days	-5.26	-4.37	ID	Days	-3.13	-2.55
SU25	Days	2.72	2.07	GSL	Days	4.13	3.67
TMAXMean	$^{\circ}\text{C}$	4.03	0.26	TXx	$^{\circ}\text{C}$	0.41	0.1
TMINMean	$^{\circ}\text{C}$	6.52	0.49	TNn	$^{\circ}\text{C}$	4.23	0.81
TN10p	Days	-6.14	-4.06	TX10p	Days	6.11	4.09
TN90p	Days	-3.36	-1.49	TX90p	Days	3.18	1.99
WSDI	Days	4.05	1.37	CSDI	Days	-3.91	-0.65
DTR	$^{\circ}\text{C}$	-5.14	-0.23				

4.2. TMAXmean, TMINmean, TXx and TNn

More than 93% of stations exhibited upward trend and most of them are significant for TMAXmean, TMINmean and TNn in the whole basin (figure 2 (E), (F) and (H)). Though TXx showed significant negative trend in the southern, it remained slightly upward trend in the whole region (figure 2 (G)). Moreover, the slope of linear tendency for TMINmean (TNn) was evidently greater than TMAXmean

(TXx) (Table 1). Therefore, the difference between high and low temperature is reducing gradually.

4.3. *TN10p, TN90p, TX10p, TX90p, WSDI and CSDI*

Almost all stations presented statistically significant positive trend for TN90p and negative trend for TN10p in the whole basin (Figure 2 (I) and (J)). TX10p and TX90p showed the similar signs as their nighttime counterparts TN10p and TN90p. And the stations having significant trend for TX10p and TX90p were generally distributed in the north of basin (Figure 2 (K) and (L)). All stations displayed positive trend for WSDI, of which 15 stations showing significant trends were mainly located in northwest of the basin (Figure 2 (M)). Negative trend was demonstrated for CSDI in most of stations (Figure 2 (N)). In almost all stations, the spatial patterns for TN90p, TX90p and WSDI are respectively opposite to TN10p, TX10p and CSDI. The trend for TN90p, TX90p and WSDI is slightly larger than TN10p, TX10p and CSDI (Table 1).

4.4. *DTR*

Except for seven stations, negative trends for DTR were demonstrated for the Haihe basin. Two-thirds stations exhibited significant negative trend for DTR (Figure 2 (O)). Therefore, local drought conditions and water resources problem will be aggravated due to the increase in temperature.

5. Conclusion

(1) All temperature indices displayed significant trend except TXx with a non-significant positive trend in the whole basin. And FD, ID, TN10p, TX10p, CSDI and DTR showed significant negative trend in the whole basin. The trends for these indices related to low temperature are larger than ones related to high temperature.

(2) TMAXmean, TMINmean and TNn had similar spatial and temporal patterns of changes in the whole basin. The trends of almost all stations for TN10p, TX10p and CSDI were generally opposite to TN90p, TX90p and WSDI.

Acknowledgements

This work was jointly financed by the National Natural Science Foundation of China (51009046, 50839002), the Natural Science Foundation of Jiangsu province (BK2010519) and the Open Research Fund Program of State Key Laboratory of Water Resources and Hydropower Engineering Science (2009B053).

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